Chapter 7
Using CAI to Provide Early Literacy Instruction for All Learners

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Abstract Identifying effective means of ameliorating achievement gaps and addressing literacy deficits is essential. Computer-assisted instruction (CAI) is one avenue for providing this effective instruction to the students that can most benefit from it. In the current study, kindergarten students in a public school district in Illinois received supplemental computer-adaptive reading instruction. Performance was assessed at the beginning and end of the kindergarten school year, and scores for students who had used the program to fidelity, at least 1500 min, were compared to the scores of students with less than 800 min of usage. Students that used the program to fidelity scored significantly higher than comparison students. Demographics in terms of special education status and ethnicity were examined, and no significant effects were found, indicating that all groups assessed were benefiting from the use of the program in comparable terms.

7.1 Introduction

Research has shown that early childhood education plays a major role in a student's later academic success [1]. Differences in student level performance, as well as stressors and environmental factors that unequally burden students from different socioeconomic and ethnic backgrounds, are identifiable early in an educational career [2]. In order to ensure all students are equally capable of achieving their greatest potential, it is important to focus on education at a young age. The past decade has seen a dramatic increase in the number of studies pertaining to educational research

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[3] and specifically research in early literacy instruction [4]. These studies can help educators and policy-makers identify high-quality interventions intended to increase universal literacy.

7.2   Literature Review

Computer-assisted instruction (CAI) involves the use of technology to facilitate education to at an individual student level [5]. CAI can be designed specifically with young learners in mind, making use of age-appropriate content and multimedia activities to foster engagement. As each student use the software, it measures their personal progress and mastery of the concepts being taught to determine whether they should be given additional instruction and scaffolding for a particular lesson. This allows for individualized lesson plans for each student, to keep them on track with learning content at their level. It also provides students and educators with direct feedback on their progress in real time, shedding light on where the students are struggling most so they can be given extra attention in those areas.

CAI has been demonstrated to be an effective tool in early childhood education. A meta-analysis from the past twenty years found an average of medium effect sizes for student learning achievement when the use of technology was incorporated in their education, and personalized learning software significantly moderated these effect sizes [6]. Research has also demonstrated that using CAI as a supplement to a student's education can be especially impactful for young learners [7]. A study of a blended learning program, in which elementary school students completed digital instructional activities alongside face-to-face traditional classroom instruction, found that students who progressed further through the individualized digital lessons during the school year experienced higher growth in reading performance by the end of the school year [8]. The most prominent gains were observed in students from kindergarten through second grade, suggesting this age range benefited the most from using the supplementary CAI.

Research has also explored the use of CAI to specifically address the achievement gap between early learners. Students with regular access to the use of computers and software are able to develop a familiarity with using these tools, allowing them to take advantage of the instructional benefits they can provide [9]. Correspondingly, students without access to technology at a young age, such as those from marginalized communities, may miss an important potential source of instruction and be at an academic disadvantage to their more digitally savvy peers [10]. However, merely having access to technology is not always enough to impact a student's learning, as not all activities that are done on a computer will lead to a specific learning outcome. One study of primarily African American students in an urban school district found an increase in reading assessment scores after students used a CAI literacy intervention [11]. Preliminary research also suggests that computer-assisted instruction may be effective for addressing achievement gaps for young African American students [12]. In a small sample study examining first-grade, African American students

receiving supplemental CAI literacy instruction, the majority of students improved their comprehension scores and reading rates.

Another population that may be able to benefit from CAI are students in special education classes. Although much of the research behind instructional methods for students with disabilities is qualitative [13], studies can provide insight about using technology to instruct these students. Special education can support students at a variety of age ranges; however, students with special education experience the most growth in reading skills at a young age [14]. Instructional multimedia activities that students experience as games can help young learners with disabilities stay engaged with the content [13]. However, some studies have suggested that CAI is not necessarily better than traditional instruction; a case study of elementary students with autism found no difference in outcomes between teaching sight words through teacher-lead instruction compared to using CAI, and these students preferred working directly with the teachers rather than the software [15]. Further research is needed to explore the use of CAI as universally beneficial tool for all students.

7.3   Research Goal

The goal of the current study is to evaluate the efficacy of Waterford Reading Academy (WRA), a CAI program to teach early literacy skills to kindergarten students. It was hypothesized that students who used the program for a meaningful amount of time during the school year would score higher on a literacy assessment at the end of the year compared to students who did not use WRA as much.

7.4   Research Methodology

7.4.1   Participants

This study consisted of kindergarten students ($N = 606$) enrolled in a public school district in Illinois during the 2021–2022 school year. The sample included 49% female, 62% African American, 22% Caucasian, and 17% received special education.

The experimental group ($n = 540$) consisted of students who used the computer-adaptive instruction program for more than 1500 min. The control group ($n = 66$) consisted of students who used the computer-adaptive instruction program for less than 800 min.

7.4.2 Materials

Waterford Reading Academy (WRA). A CAI reading curriculum for early learners. The software utilizes a broad spectrum of educational media in a sequence customized to each student's specific ability and pace of development.

Northwest Evaluation Association (NWEA) Measures of Academic Progress (MAP) Growth. The MAP Growth is a valid assessment intended to measure individual achievement and growth. The skills considered relevant to kindergarten students for this study are the Overall RIT Reading, Foundational Skills, Language and Writing, Literature and Informational Text, and Vocabulary Use and Functions.

7.4.3 Procedure

Students were expected to use WRA for fifteen minutes per day, five days per week. Usage was tracked within the program and total minutes of the adaptive program usage was calculated. The MAP Growth assessment was administered to all students at the beginning and end of the school year to assess literacy.

7.5 Research Outcomes

7.5.1 Baseline Equivalence Using Independent Samples t-*tests*

Independent samples *t*-tests were conducted to determine baseline equivalence of pretest scores at the beginning of the school year between experimental and control groups. Across all subskills, baseline scores were not significantly different between the students in the experimental and control groups (see Table 7.1).

Table 7.1 MAP growth reading beginning of year scores by subskill

Subskill	Experimental		Control			
	N	*M*	*N*	*M*	*t*	*p*
Overall RIT reading	511	134.57	34	134.50	−0.03	0.977
Foundational skills	509	131.33	34	131.44	0.06	0.954
Language and writing	511	135.29	34	137.44	0.86	0.393
Literature and informational text	510	136.76	34	135.21	−0.78	0.435
Vocabulary use and functions	511	134.99	34	133.91	−0.42	0.679

7.5.2   Post-test Group Differences Using Independent Samples t-tests

Independent samples *t*-tests were conducted to examine group differences in end of year scores between experimental and control groups (see Fig. 7.1).
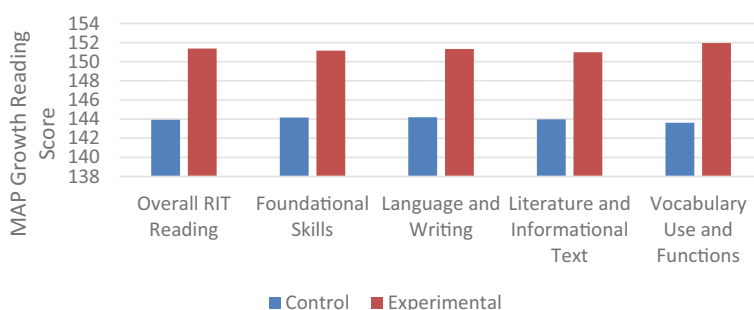
Overall RIT Reading. Analysis of Overall RIT Reading end of year scores revealed a significant difference between groups, $t(1, 604) = -4.67$, $p < 0.001$, due to higher end of year scores made by experimental students ($M = 151.37$) than by control students ($M = 143.92$). Effect size ($d = 0.61$).

Foundational Skills. Analysis of Foundational Skills end of year scores revealed a significant difference between groups, $t(1, 604) = -3.98$, $p < 0.001$, due to higher end of year scores made by experimental students ($M = 151.15$) than by control students ($M = 144.17$). Effect size ($d = 0.52$).

Language and Writing. Analysis of Language and Writing end of year scores revealed a significant difference between groups, $t(1, 604) = -4.31$, $p < 0.001$, due to higher end of year scores made by experimental students ($M = 151.33$) than by control students ($M = 144.20$). Effect size ($d = 0.56$).

Literature and Informational Text. Analysis of Literature and Informational Text end of year scores revealed a significant difference between groups, $t(1, 603)$ $= -3.82$, $p < 0.001$, due to higher end of year scores made by experimental students ($M = 150.99$) than by control students ($M = 143.97$). Effect size ($d = 0.50$).

Vocabulary Use and Functions. Analysis of Vocabulary Use and Functions end of year scores revealed a significant difference between groups, $t(1, 604) = -4.16$, $p < 0.001$, due to higher end of year scores made by experimental students ($M = 151.95$) than by control students ($M = 143.62$). Effect size ($d = 0.54$).

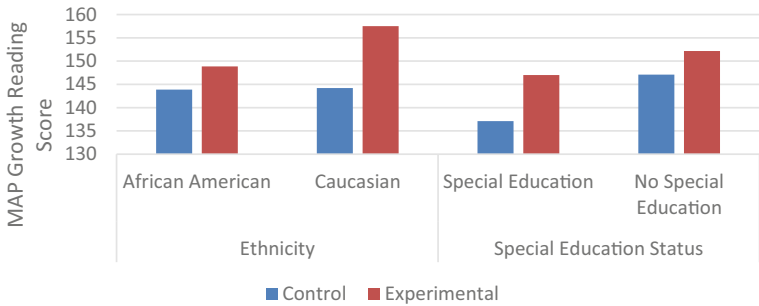**Fig. 7.1** MAP growth reading end of year scores by subskill

Fig. 7.2 Overall RIT reading end of year scores by demographics

7.5.3   Post-test Group Differences Using ANOVAs

Overall RIT Reading. Two separate two-way ANOVAs were conducted to examine the effects of WRA and demographics on Overall RIT Reading end of year scores (see Fig. 7.2).

Ethnicity. There was no significant interaction between the effects of ethnicity and WRA on Overall RIT Reading end of year scores, $F(3, 596) = 1.29, p = 0.278$. Simple effects analysis showed that for African American and Caucasian students, students in the experimental group significantly outperformed students in the control group.

Special Education Status. There was no significant interaction between the effects of special education status and WRA on Overall RIT Reading end of year scores, $F(1, 602) = 1.94, p = 0.164$. Simple effects analysis showed that for students with special education and students without special education, students in the experimental group significantly outperformed students in the control group.

Foundational Skills. Two separate two-way ANOVAs were conducted to examine the effects of WRA and demographics on Foundational Skills end of year scores (see Fig. 7.3).
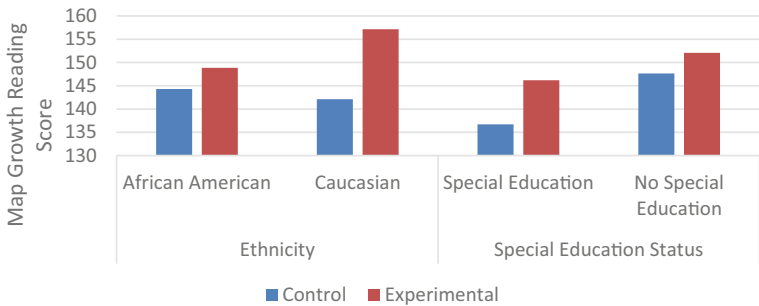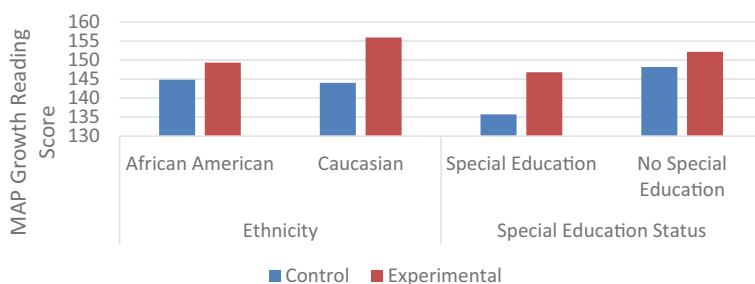

Fig. 7.3 Foundational skills end of year scores by demographics

Fig. 7.4 Language and writing end of year scores by demographics

Ethnicity. There was no significant interaction between the effects of ethnicity and WRA on Foundational Skills end of year scores, $F(3, 596) = 2.14$, $p = 0.094$. Simple effects analysis showed that for African American and Caucasian students, students in the experimental group significantly outperformed students in the control group.

Special Education Status. There was no significant interaction between the effects of special education status and WRA on Foundational Skills end of year scores, $F(1, 602) = 1.74$, $p = 0.188$. Simple effects analysis showed that for students with special education and students without special education, students in the experimental group significantly outperformed students in the control group.

Language and Writing. Two separate two-way ANOVAs were conducted to examine the effects of WRA and demographics on Language and Writing end of year scores (see Fig. 7.4).

Ethnicity. There was no significant interaction between the effects of ethnicity and WRA on Language and Writing end of year scores, $F(3, 596) = 1.06$, $p = 0.367$. Simple effects analysis showed that for African American and Caucasian students, students in the experimental group significantly outperformed students in the control group.

Special Education Status. There was no significant interaction between the effects of special education status and WRA on Language and Writing end of year scores, $F(1, 602) = 3.82$, $p = 0.051$. Simple effects analysis showed that for students with special education and students without special education, students in the experimental group significantly outperformed students in the control group.

Literature and Informational Text. Two separate two-way ANOVAs were conducted to examine the effects of WRA and demographics on Literature and Informational Text end of year scores (see Fig. 7.5).

Ethnicity. There was no significant interaction between the effects of ethnicity and WRA on Literature and Informational Text end of year scores, $F(3, 595) = 0.73$, $p = 0.536$. Simple effects analysis showed that for African American and Caucasian students, students in the experimental group significantly outperformed students in the control group.
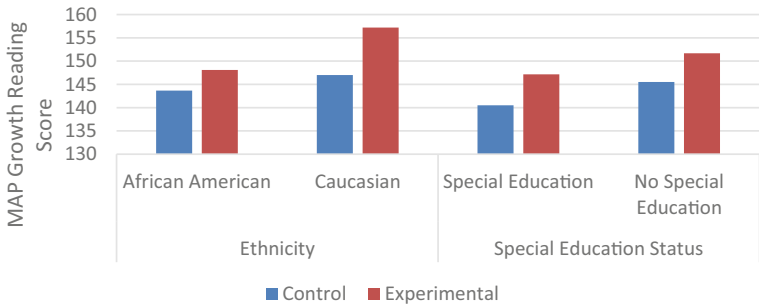
Fig. 7.5 Literature and informational text end of year scores by demographics

Special Education Status. There was no significant interaction between the effects of special education status and WRA on Literature and Informational Text end of year scores, $F(1, 601) = 0.01$, $p = 0.905$. Simple effects analysis showed that students without special education in the experimental group significantly outperformed students in the control group. Students with special education in the experimental group scored slightly higher than the control group, but the difference was not significant.

Vocabulary Use and Functions. Two separate two-way ANOVAs were conducted to examine the effects of WRA and demographics on Vocabulary Use and Functions end of year scores (see Fig. 7.6).

Ethnicity. There was no significant interaction between the effects of ethnicity and WRA on Vocabulary Use and Functions end of year scores, $F(3, 596) = 1.29$, $p = 0.276$. Simple effects analysis showed that for African American and Caucasian students, students in the experimental group significantly outperformed students in the control group.

Special Education Status. There was no significant interaction between the effects of special education status and WRA on Vocabulary Use and Functions end of year scores, $F(1, 602) = 1.34$, $p = 0.247$. Simple effects analysis showed that for
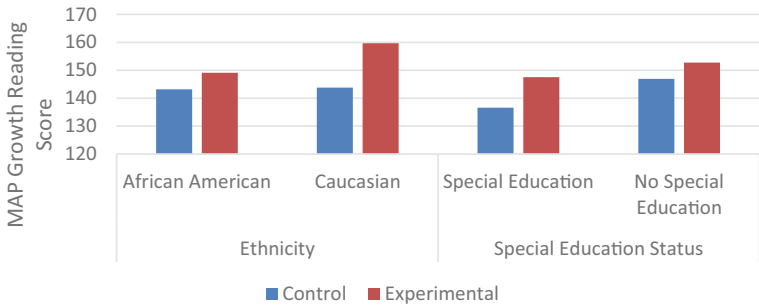
Fig. 7.6 Vocabulary use and functions end of year scores by demographics

students with special education and students without special education, students in the experimental group significantly outperformed students in the control group.

7.6   Discussion

The results of the current study are consistent with previous findings that CAI can be an effective resource to supplement young students' learning [6]. While students had similar literacy scores on average at the beginning of the year, students in the experimental group who used the supplemental CAI software to fidelity throughout the school year achieved significantly higher literacy scores when assessed at the end of the school year compared to their control group counterparts. Overall effect sizes ranged from 0.50 to 0.61, indicating a medium effect across each of the measured subskills. These results demonstrate that the use of CAI as a supplement to traditional classroom learning can have a significant impact on students' literacy outcomes.

7.7   Conclusions

Among the most important considerations when implementing a CAI program is that it benefits all students [10]. Analysis by the available demographic data showed no interaction effect between group assignment and demographics, indicating that all students in the experimental group scored higher on the end of year literacy assessment on average, regardless of ethnicity or special education status. African American students as well as Caucasian students within the experimental group significantly outperformed their control group counterparts across all literacy subskills. Results by special education status were also strong, as scores for students with and without special education were significantly higher in the experimental group than the control group for all subskills, with the exception of Literature and Informational Text, where experimental group students with special education slightly outperformed the control group, but the results were not significant. Particularly noteworthy is that across all subskills, students with special education in the experimental group scored similarly to students without special education in the control group, essentially catching up to their peers that were not part of special education after one year of using WRA. Overall, this indicates that WRA provided a meaningful impact in early literacy skills across all of the students in the sample.

7.8   Next Steps

One of the limitations of the current study is that students were only observed over the course of a single school year. Future research would benefit from following up

with students one or more years after using WRA, measuring the degree to which this type of early literacy instruction can impact students' later academic success.

References

1. McCoy, D.C., Yoshikawa, H., Zio-Guest, K.M., Duncan, G.J., Schindler, H.S., Magnuson, K., Yang, R., Koepp, A., Shonkoff, J.P.: Impacts of early childhood education on medium and long-term educational outcomes. Educ. Res. **46**(8), 474–487 (2017)
2. Merolla, D.M., Jackson, O.: Structural racism as the fundamental cause of the academic achievement gap. Sociol. Compass **13**(6), e12696 (2019)
3. Gopalan, M., Rosinger, K., Ahn, J.B.: Use of quasi-experimental research designs in education research: growth, promise, and challenges. Rev. Res. Educ. **44**(1), 218–243 (2020)
4. Hoffman, E.B., Whittingham, C.E., Teale, W.H.: A decade of early literacy research: who did what, where, and to what end? Read. Teach. **72**(3), 283–288 (2018)
5. Jacob, B., Berger, D., Hart, C., Loeb, S.: Can technology help promote equality of educational opportunities? RSF Russell Sage Found. J. Soc. Sci. **2**(5), 242–271 (2016)
6. Zheng, L., Long, M., Zhong, L., Gyasi, J.F.: The effectiveness of technology-facilitated personalized learning on learning achievements and learning perceptions: a meta-analysis. Educ. Inf. Technol. **27**, 1–24 (2022)
7. Wilkes, S., Kazakoff, E. R., Prescott, J. E., Bundschuh, K., Hook, P. E., Wolf, R., Macaruso, P, et al.: Measuring the impact of a blended learning model on early literacy growth. J. Comput. Assist. Learn. **36**(5), 595–609 (2020)
8. Prescott, J.E., Bundschuh, K., Kazakoff, E.R., Macaruso, P.: Elementary school–wide implementation of a blended learning program for reading intervention. J. Educ. Res. **111**(4), 497–506 (2018)
9. Israel, M., Pearson, J.N., Tapia, T., Wherfel, Q.M., Reese, G.: Supporting all learners in school-wide computational thinking: a cross-case qualitative analysis. Comput. Educ. **82**, 263–279 (2015)
10. Rowsell, J., Morrell, E., Alvermann, D.E.: Confronting the digital divide: debunking brave new world discourses. Read. Teach. **71**(2), 157–165 (2017)
11. Council, M.R., III., Gardner, R., III., Cartledge, G., Telesman, A.O.: Improving reading within an urban elementary school: computerized intervention and paraprofessional factors. Preventing School Fail. Altern. Educ. Child. Youth **63**(2), 162–174 (2019)
12. Gibson, L., Cartledge, G., Keyes, S.E.: A preliminary investigation of supplemental computer-assisted reading instruction on the oral reading fluency and comprehension of first-grade African American urban students. J. Behav. Educ. **20**(4), 260–282 (2011)
13. Koh, C.: A qualitative meta-analysis on the use of serious games to support learners with intellectual and developmental disabilities: What we know, what we need to know and what we can do. Int. J. Disabil. Dev. Educ. **69**(3), 919–950 (2022)
14. Mize, M.K., Park, Y., Moore, T.: Computer-assisted vocabulary instruction for students with disabilities: evidence from an effect size analysis of single-subject experimental design studies. J. Comput. Assist. Learn. **34**(6), 641–651 (2018)
15. Johnson, A.M., Nikolaros, J.: Problem based learning in a special needs environment. Clute Int. Conf. San Francisco Proc. **2018**, 186–190 (2018)